NASA SnowEx 2020

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Time Series Leads, Aircraft Teams, Field Teams, Partnerships

Photo Credit, Andrew Hedrick

SnowEx 2019 Workshop, September 17-18
Baltimore, Maryland

SnowEx 2020

The SnowEx 2020 Campaign consists of coordinated airborne and field-based experiments in the Western U.S. to test instruments under a variety of snow conditions. This effort includes two major components:

1. **A time series experiment with UAVSAR**
   - 13 sites, spanning 5 states
   - December 18, 2019 to May 6, 2020, with weekly to bi-weekly (fortnightly) aircraft overflights and field campaigns
2. **A detailed experiment on Grand Mesa, Colorado**
   - 5-day snow-off campaign November 4-8, 2019
   - 10-day snow-on campaign January 27 –February 7, 2020

Alignment with THP16 Science Plan

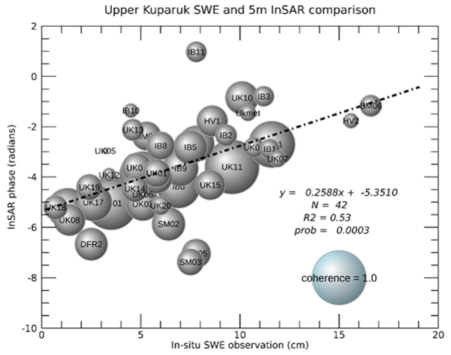
SnowEx 2020: Responds to 6 out of 7 Science Plan Gaps

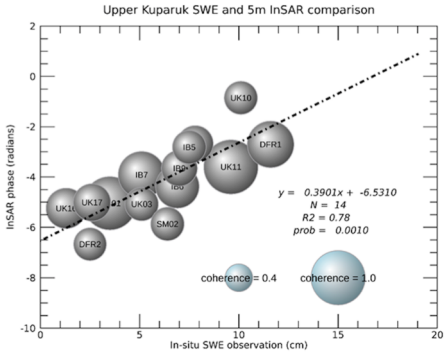
- Snow climates (Forest, mountain, prairie, maritime)
- Wet snow, accumulation and melt (time series)
- Surface energetics (surface temperature)

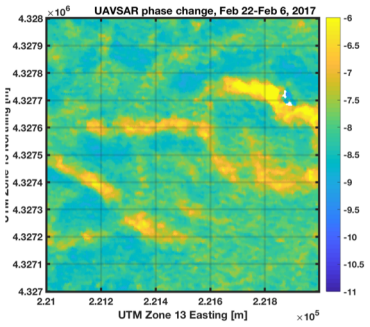
SnowEx 2020: Responds to all Science Plan *Mission Critical, Crucial*, *Important* priorities

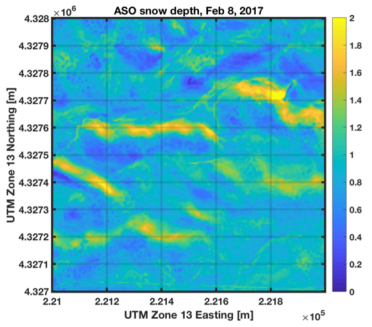
- X-band, dual Ku-band SAR (SWESARR)
- L-band InSAR (UAVSAR)
- Ka-band InSAR (GLISTIN-A)
- LiDAR (ASO, CRREL HeliPod)
- Thermal IR (UW, CRREL HeliPod)
- X-, K-, Ka-band Passive microwave (SWESARR)
- Hyperspectral imaging (ASO, CRREL HeliPod)
- Modeling / Data Assimilation (SEUP, NOHRSC)
- Photogrammetry / Structure from Motion (airborne and satellite based)
- FMCW radar (similar to IceBridge SnowRadar; University of Alabama)

L-band InSAR: Previous Results





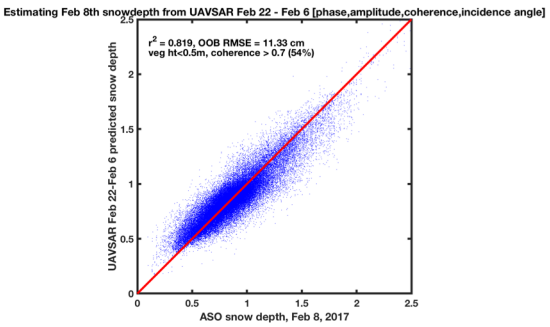


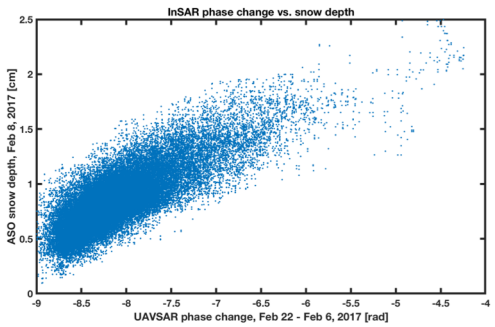


1. **A time series experiment with UAVSAR**
   - Correlation increases with coherence

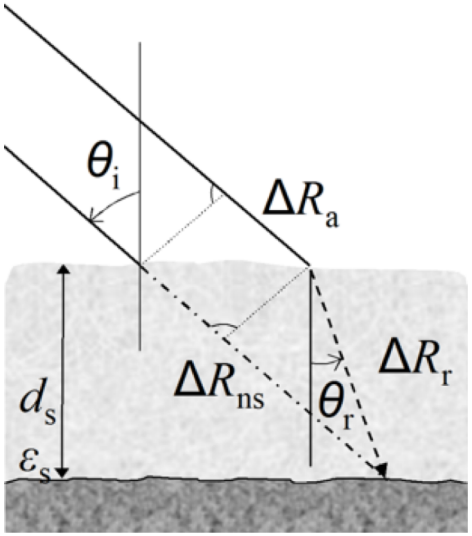
   [PALSAR, Deeb et al., in review]
   - SnowEx17 UAVSAR phase change correlated with total snow depth

   [UAVSAR, Marshall et al., AMS 2019]



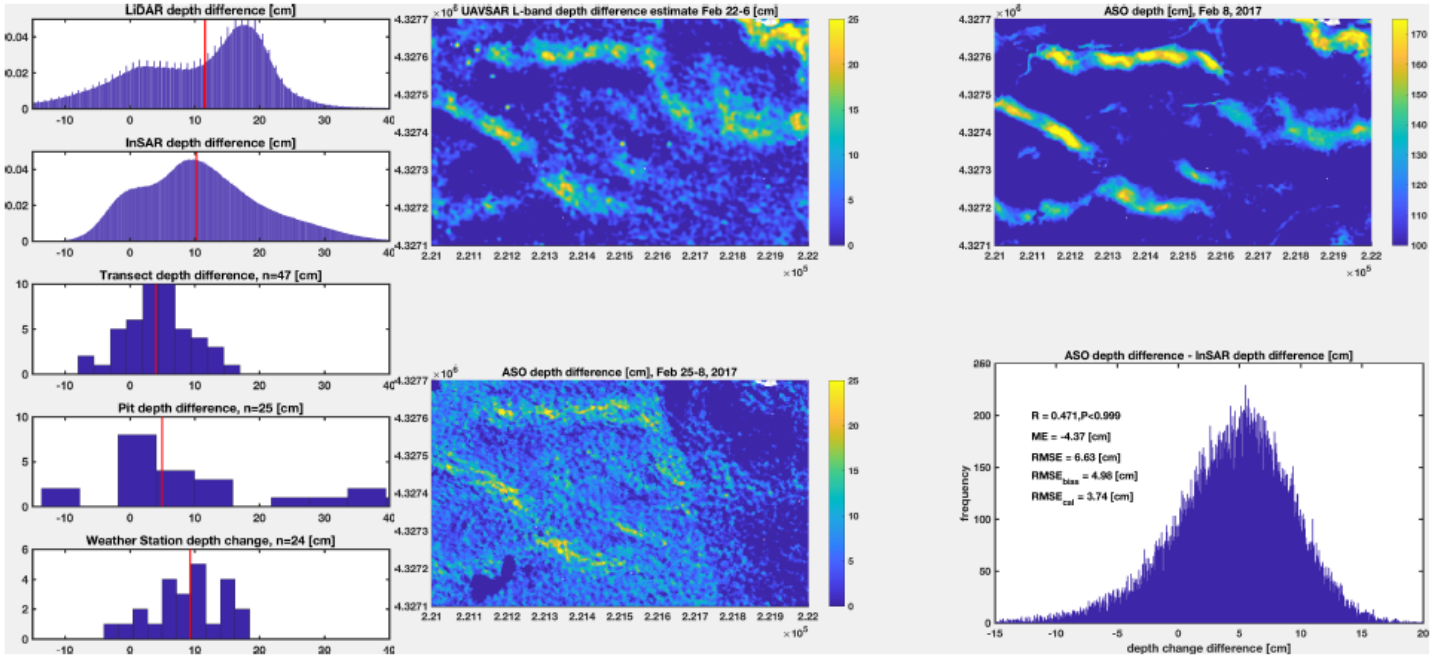


L-band InSAR: Inverting for depth change



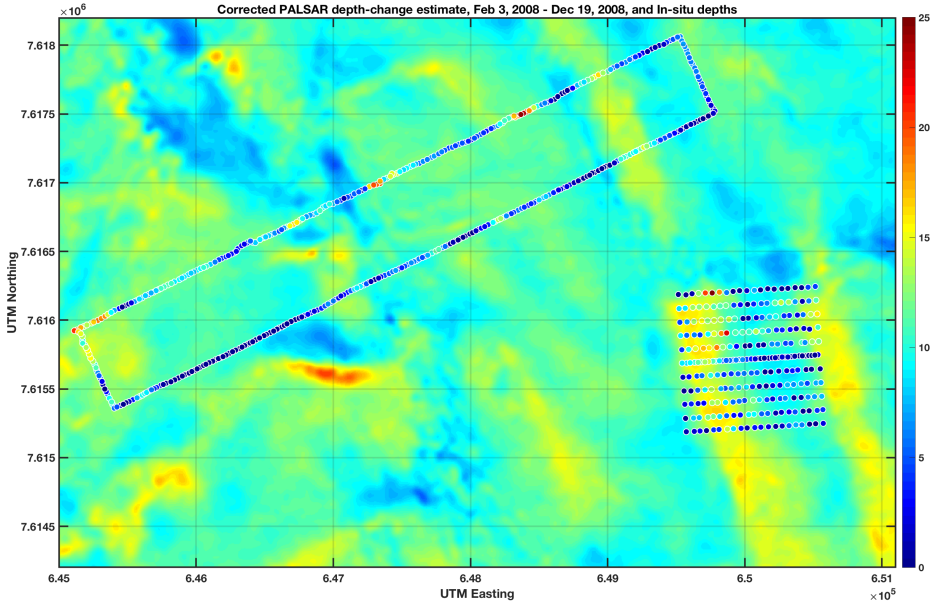
[e.g., Gunnerison et al., 2001]

$$\Delta d = -\frac{\Delta\phi\,\lambda}{4\pi}\,\frac{1}{\cos\alpha - \sqrt{\epsilon_s - \sin^2\alpha}}$$



SnowEx 2020 – UAVSAR

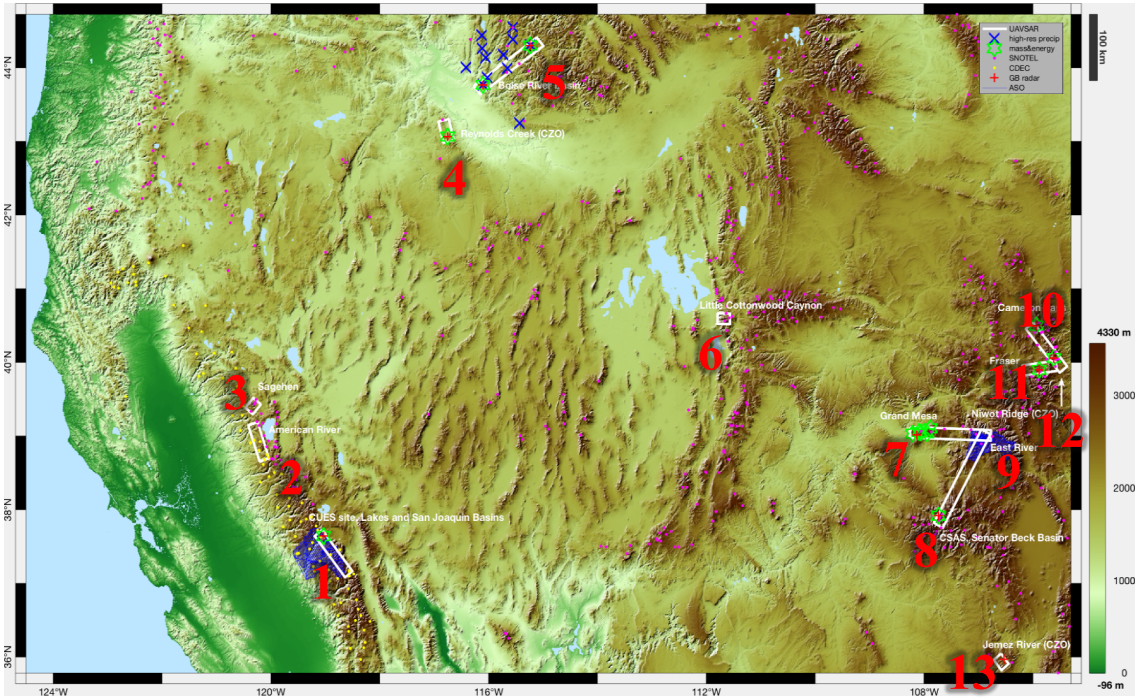
- L-band Interferometric Synthetic Aperture Radar
  - L-Band (1 GHz; 23 cm)
  - Weekly to biweekly flights, Dec-May
  - Relationship between change in SWE/depth vs. change in InSAR phase
- Validation for a range of snow climates, vegetation, and during accumulation & melt
- Opportunity for further validation in preparation for NASA-ISRO SAR (**NISAR**) satellite mission, https://nisar.jpl.nasa.gov
  - L- and S-band (12 cm)
  - 12-day (or shorter) exact repeat orbit
  - Launch date: Dec. 2021
  - 3-10 m resolution



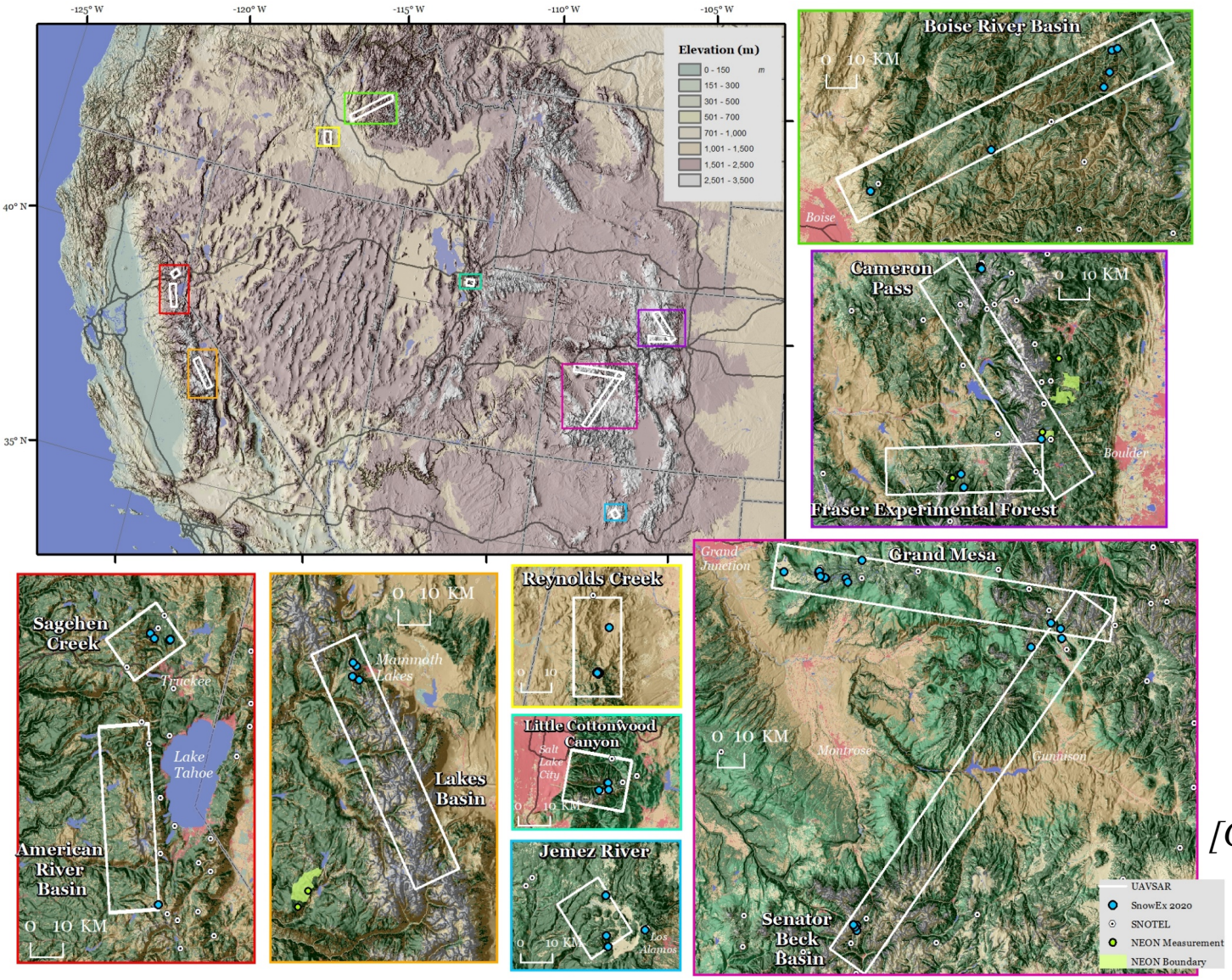
North Slope Brooks Range, AK
[from E. Deeb]

Previous studies have found agreement in accumulation patterns, compared to LiDAR and magnaprobe depth observations

SnowEx 2020 – Time Series



Site	Site Name	Site Lead
1	Lakes Basin, CA	Ned Bair
2	American River Basin, CA	Roger Bales
3	Sagehen Creek, CA	Anne Nolin
4	Reynolds Creek, ID	Ernesto Trujillo
5	Boise River Basin, ID	Jim McNamara
6	Little Cottonwood Canyon, UT	McKenzie Skiles
7	Grand Mesa, CO	Hiemstra, Brucker
8	Senator Beck Basin, CO	Andy Gleason
9	East River, CO	Jeff Deems
10	Cameron Pass, CO	Dan McGrath
11	Fraser Experimental Forest, CO	Kelly Elder
12	Niwot Ridge, CO	Noah Molotch
13	Jemez River, NM	Ryan Webb



Sites cover a wide range of snow climatology, land cover, and topography

Leveraging THP16/17 projects, Critical Zone Observatories (CZO) sites, LTER sites, and other long term observations in critical watersheds

[Chris Hiemstra, 2019]

SnowEx 2020 – Time Series

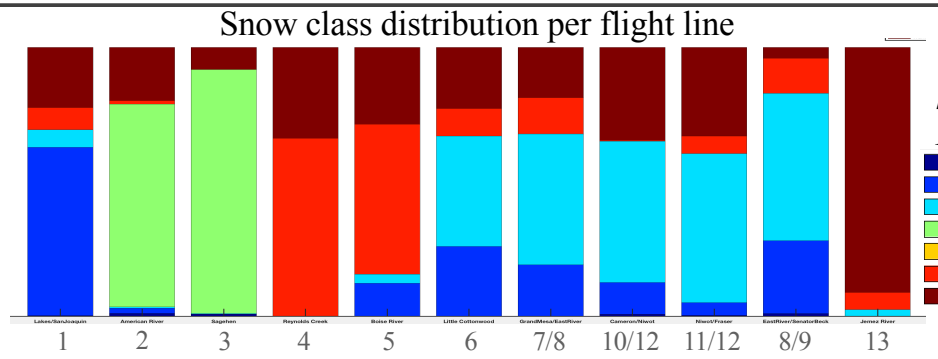
Focus on variability of snow and landscape conditions throughout the accumulation and melt season.

Ground observations of:

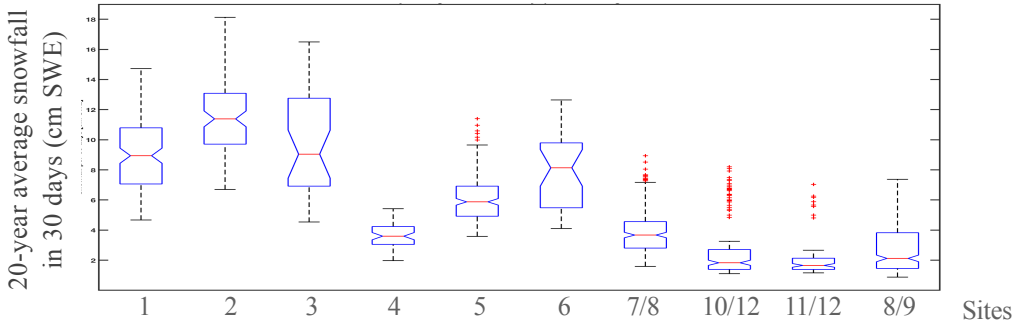
- Change in snow depth and SWE
- Snow stratigraphy, density, and liquid water content
- Ground-based radar (CSU, UNM, BSU)
- Terrestrial LiDAR (CRREL, BSU)
- Field spectrometer (Univ UT, UNR)

Airborne observations of:

- L-band InSAR (UAVSAR)
- Airborne LiDAR (ASO, CRREL, etc)
- Ka-band InSAR (GLISTIN-A (CA))

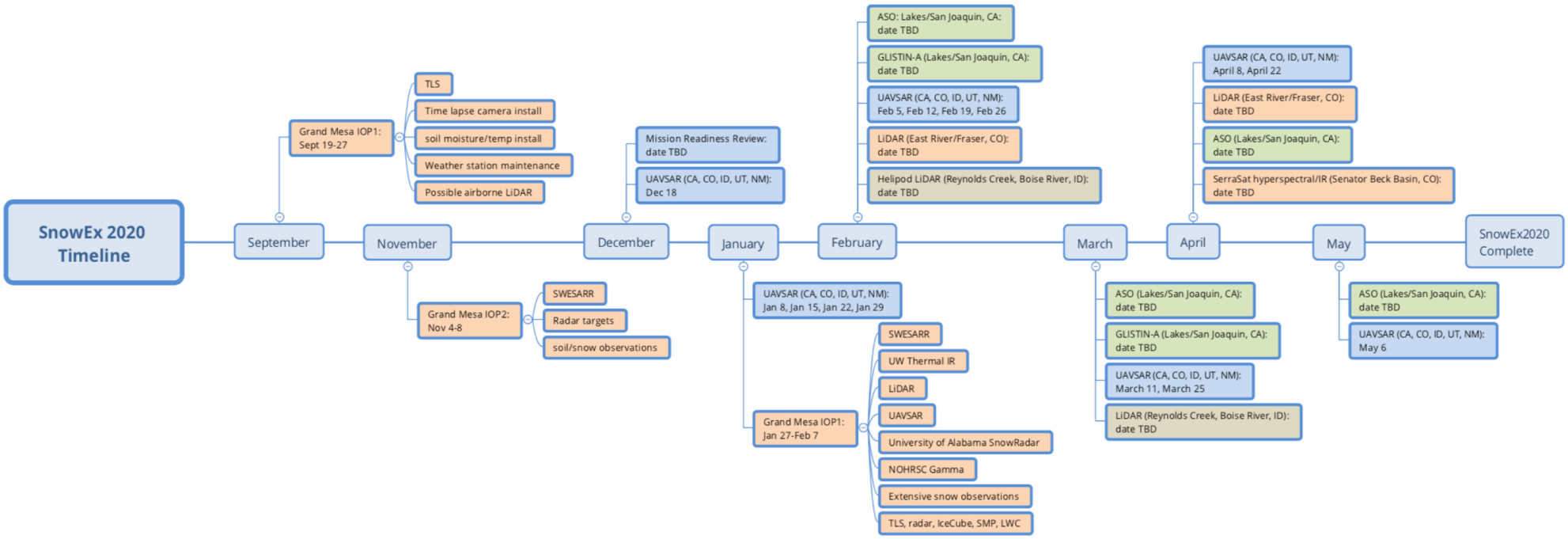


[Sturm and Liston, 1995]



[Liston 20-yr N. America SnowModel simulation]

SnowEx 2020 – Schedule



SnowEx 2020 – Grand Mesa

Primary Objectives:

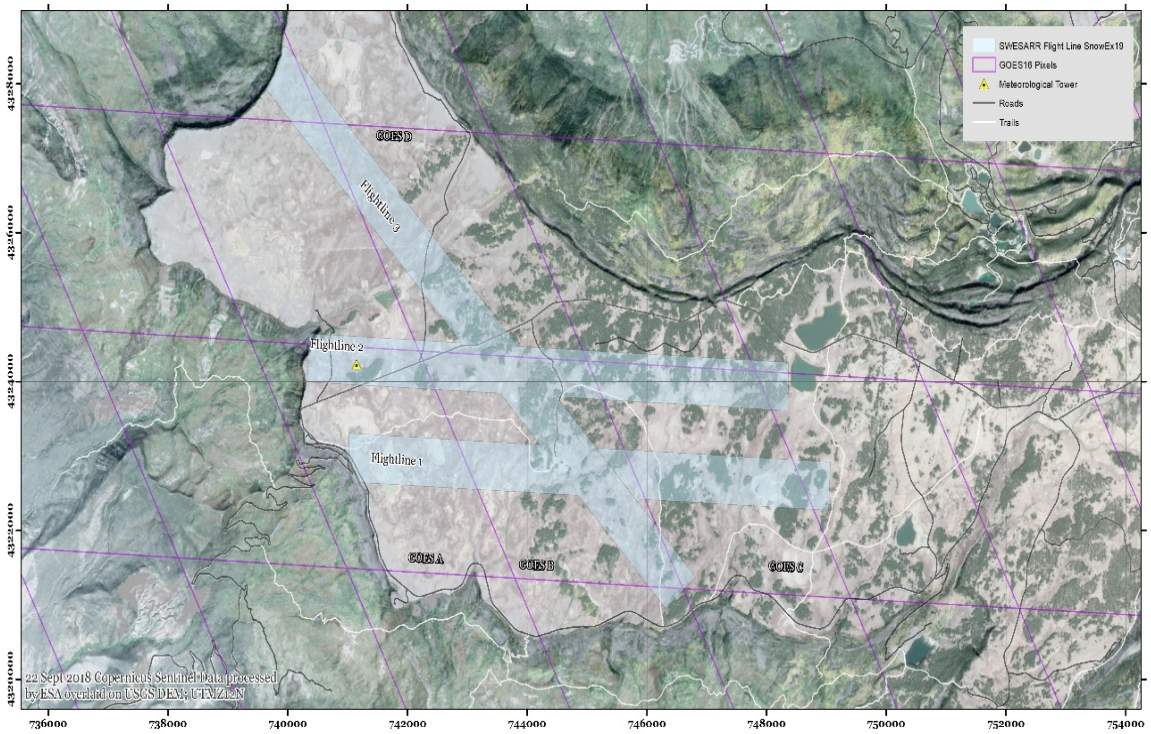
1. Collect data needed test and validate SWE retrieval from active and passive microwave sensors
2. Collect thermal IR data to assess the value of kilometer-scale satellite IR observations (e.g., GOES-16/17) for snow energy balance modeling

- Focus on flat, open shrubland and meadows and transitioning into forests
- Ground observations of:
  - Snow depth and surface temperature spatial variability
  - Vertical profiles of snow stratigraphy and microstructure

Grand Mesa Airborne instruments

Airborne observations of:

- X-, dual Ku-band radar (NASA GSFC SWESARR)
- X, K-, Ka-band radiometer (NASA GSFC SWESARR)
- Thermal IR (U. of Washington)
- LiDAR and Hyperspectral (Quantum Spatial)
- L-band InSAR (UAVSAR)
- FMCW Snow Radar (U. of Alabama)
- Gamma Airborne Survey (NOAA NOHRSC)



Grand Mesa – SWESARR

Snow Water Equivalent Synthetic Aperture Radar & Radiometer (SWESARR)

- Recently developed GSFC instrument
- A single antenna for a triple-band SAR & Radiometer

	Band	f (GHz)	BW (MHz)	Pol
Active	X	9.65	200	VV,VH
Active	Ku-Lo	13.60	200	VV, VH
Active	Ku-Hi	17.25	100	VV, VH
Passive	X	10.65	200	H
Passive	K	18.70	200	H
Passive	Ka	36.50	1000	H

Photo: R. Rincon (GSFC)

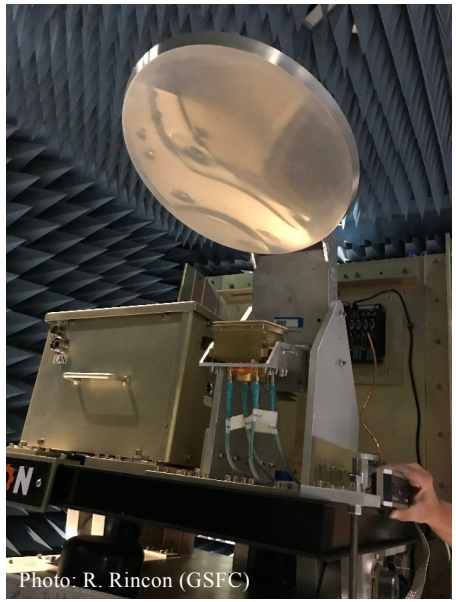


Photo: R. Rincon (GSFC)

Anechoic chamber tests

- Successful engineering flights in Dec. 2018 on Grand Mesa

Airborne Thermal IR

University of Washington - Compact Airborne System for Imaging the Environment (CASIE)

TIR sensor suite:

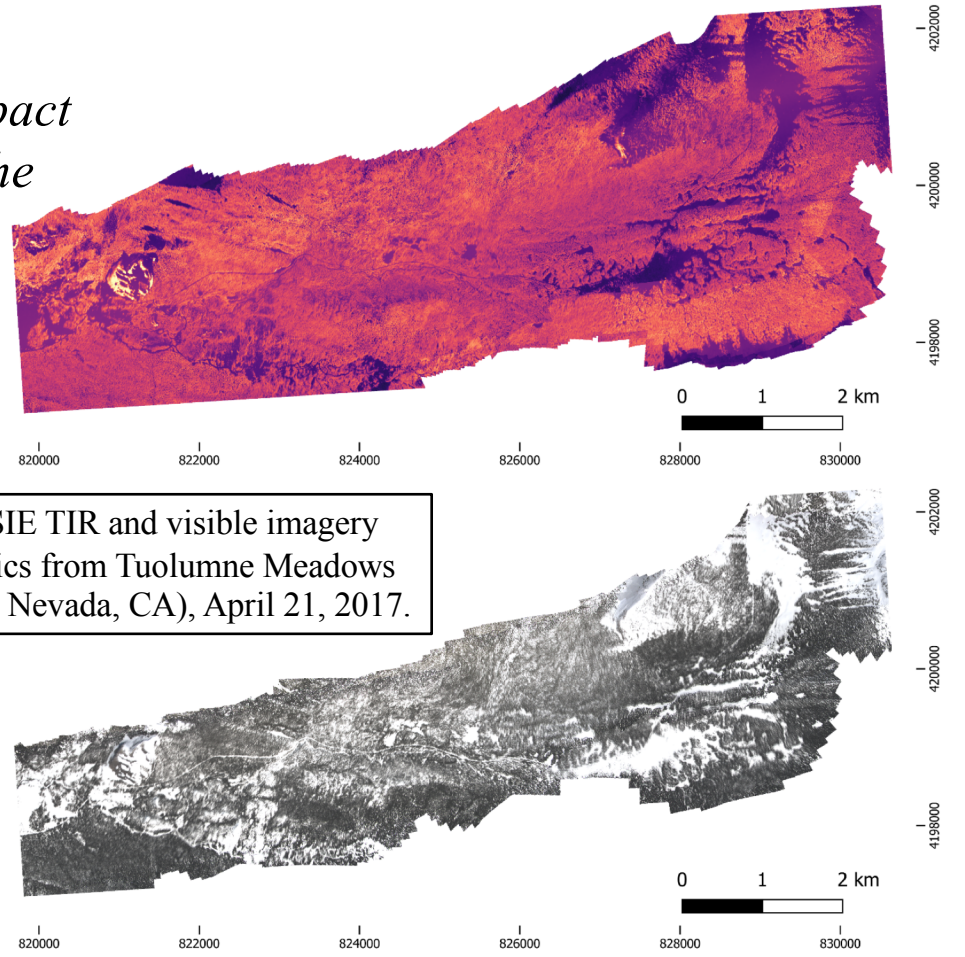
- 3 TIR cameras
- KT-15 radiometer for TIR camera calibration
- Visible imagery camera

Science objectives:

- Subpixel temperature distributions for comparison with satellite observations
- Surface energy balance model evaluation

Grand Mesa IOP Observations:

- Calibrated surface temperature maps
- Visible imagery
- Ground-based snow surface temperature point measurements for validation of airborne IR data

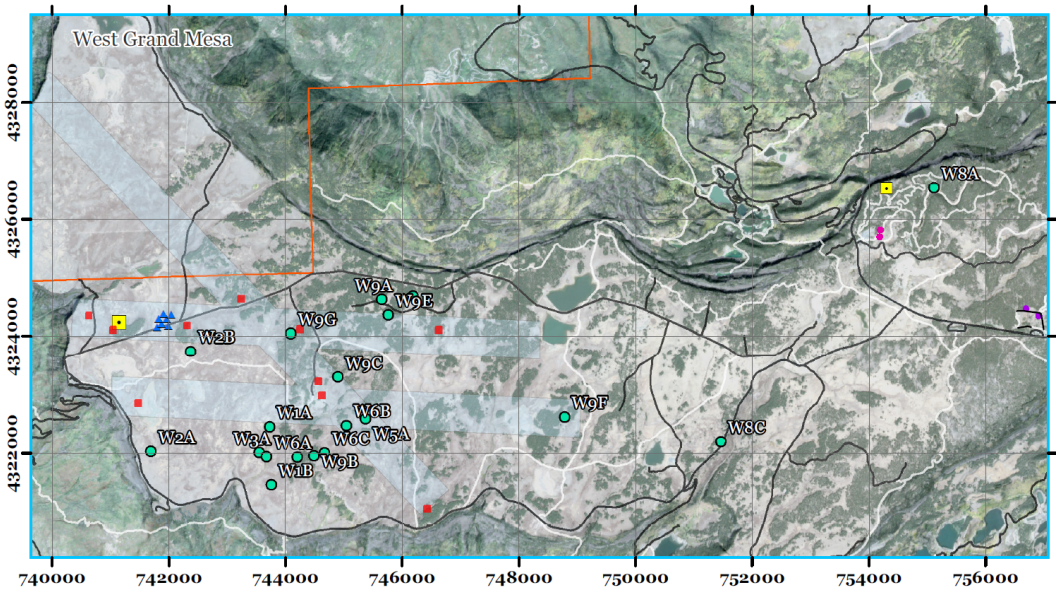


CASIE TIR and visible imagery mosaics from Tuolumne Meadows (Sierra Nevada, CA), April 21, 2017.

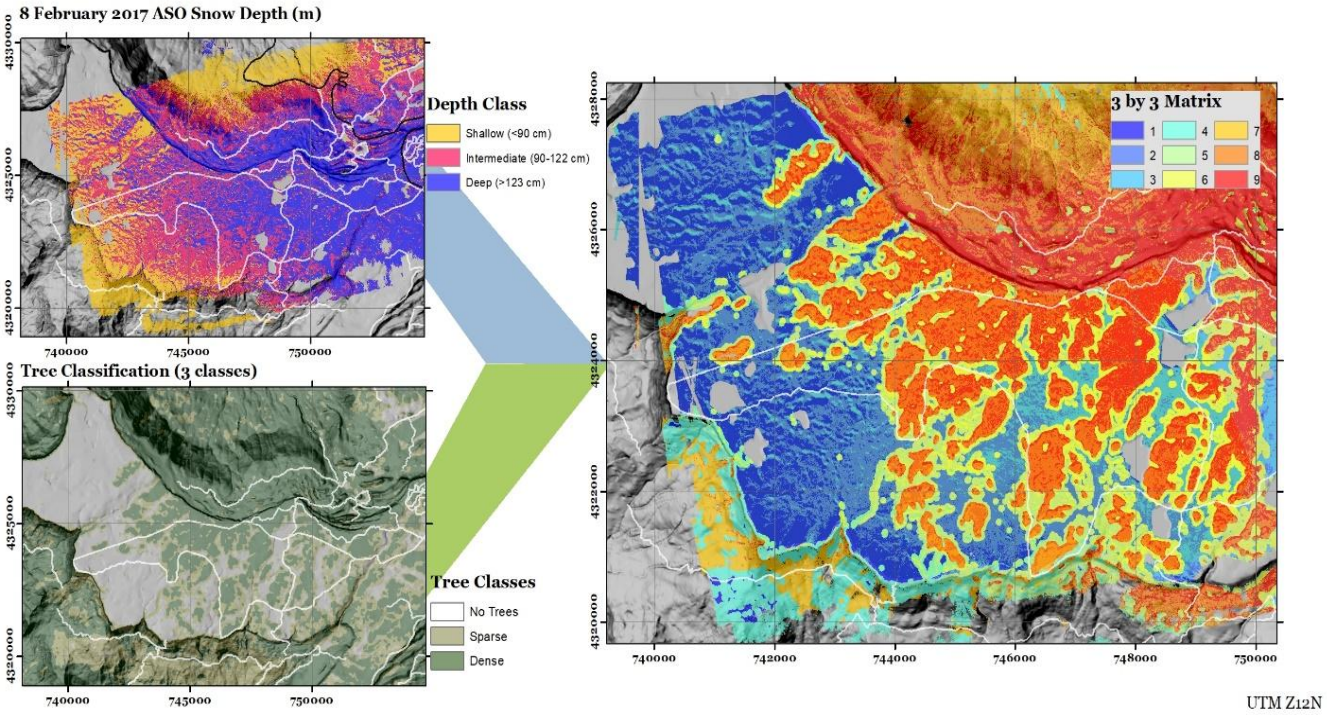
Grand Mesa Ground-based instruments

Ground-based Instruments:

- Terrestrial Laser Scanner (TLS)
- Magnaprobe
- Ground penetrating radar
- Snow micropenetrometer (SMP)
- IceCube/IRIS
- Snow casting/Micro-CT
- Snow surface temperature
- In situ soil moisture and temperature sensors
- COSMOS Sensor, in situ soil moisture and SWE



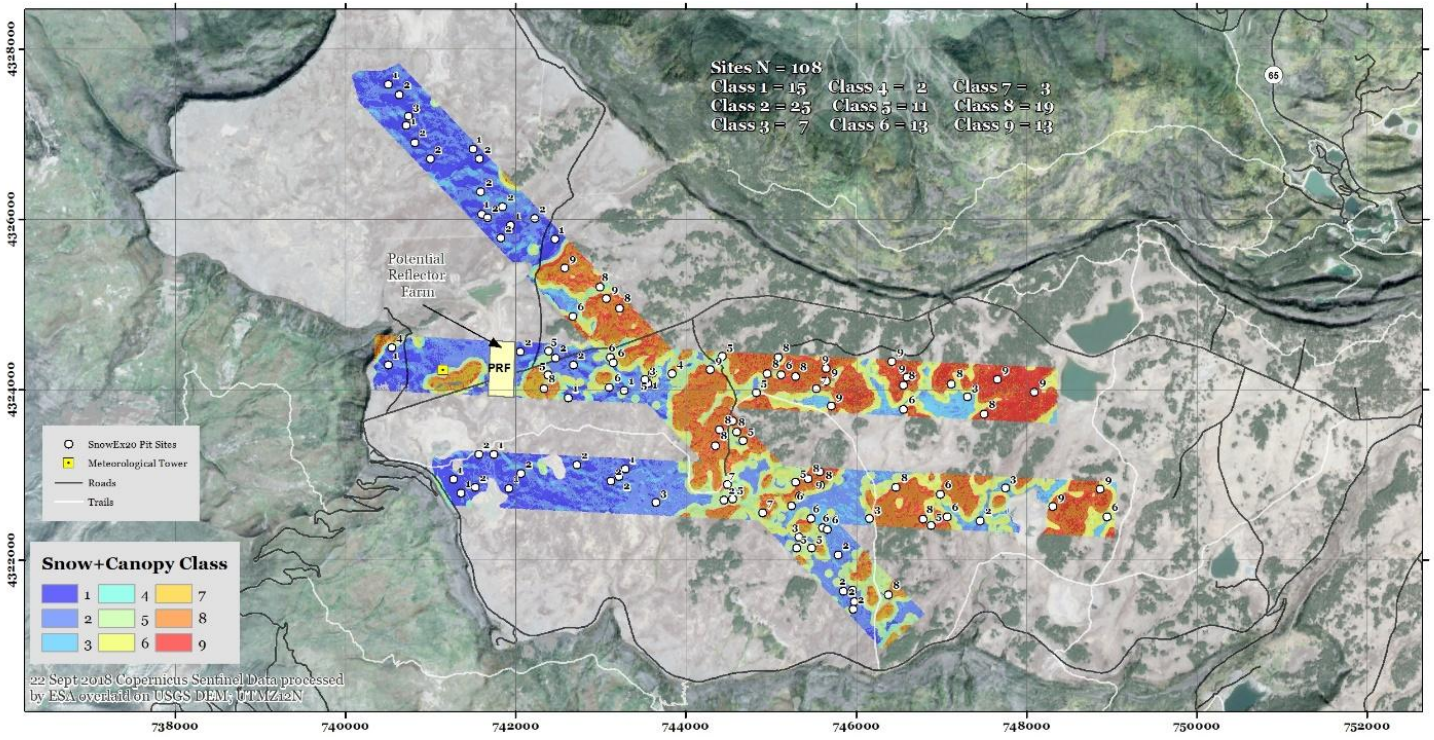
Grand Mesa Ground Classification



Ground sampling locations were determined using ASO snow depth from 2017 and a vegetation classification scheme

Locations were randomly selected to match spatial distribution of classification within SWESARR swath.

Grand Mesa Ground Sampling locations



Ground Observations:

- Snow depth
- Snow surface roughness
- Stratigraphy
- Density
- Wetness
- Temperature
- Grain Size
- Soil Characteristics

SnowEx 2020 – Current Collaborations/Coordination

In situ

Bi-weekly in situ sampling (Colorado, Idaho)
Natural Resources Conservation Service (NRCS)

Airborne

LiDAR flights (East River, Colorado and San Joaquin/Lakes, California)
ASO

Helipod LiDAR/thermal infrared (Boise River Basin, Idaho)
U.S. Army Corps of Engineers, CRREL

UltraWideBand radar (2-18 GHz) (Grand Mesa, Colorado)
Uni. of Alabama

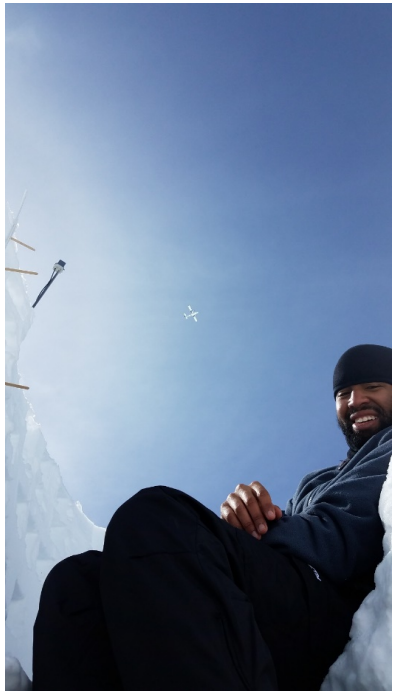
Signal of Opportunity (SoOp) tower experiment (Fraser, Colorado)
JPL / U.S. Forest Service

Gamma flights (Colorado, possibly other states)
NOAA National Operational Hydrologic Remote Sensing Center (NOHRSC)

Satellite

Stereo satellite imagery (e.g., World View, TerraSAR-X)
U. of Washington, U.S. Army Corps of Engineers, CRREL

Sentinal-1/2 C-band SAR
FMI, KU Leuvens (will also provide 1km SWE products)



Modeling

Several modeling efforts focused on most sites (e.g., NOHRSC; Snow Ensemble Uncertainty Project – SEUP)

SnowEx 2020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Experiment Plan

Draft (July 2019)

NASA

Draft Experiment Plan:

https://tinyurl.com/y4r6oz9d